A flexibly linkable meta layer of geographic features supplementary for driving automation and simulation

DSC 2020 Europe VR

Rüdiger Ebendt

DLR

Motivation 1(2)

- **High Definition (HD) Maps: which is the “best” format?**
  - OpenDRIVE
  - IPG ROAD5
  - NDS Open Lane Model (Navigation Data Standard)
  - Lanelet/Lanelet2
  - TomTom HD Map RoadDNA
  - Here HD Live Map
  - …or even OpenStreetMap (OSM)?
    - Open source maps and community crowdsourcing approaches are emerging with OpenStreetMaps (OSM)
    - Some vendors and a rising number of start-ups use them as a basis for navigable maps with additional navigation-related attributes generated via AI tools
    - Scientific progress in the use of OSM data for global path planning or (even small scale) localization
  - This may also put Standard Definition (SD) maps from Here, TomTom etc. back into play

Motivation 2(2)

- **Lack of standards**: Despite ongoing standardization efforts such as NDS, ADASIS, SENSORIS, TISA, etc., which are overlooked by OADF, "maps are still essentially proprietary datasets lacking interoperability between mapping suppliers" (ABI Research / HERE, 2018).

- Even if a "best" standard could be identified: With respect to what **purpose**, such as driving automation / ADAS or driving simulation, would it be "best"?
  - Example: Different requirements on relative and absolute errors for simulation and ADAS

- Different types of map content:
  - **3D representations of**
    - buildings and various types of landmarks
    - slope and curvature of roads, lane markings, and roadside objects, such as sign posts
  - **Street level, aerial, and satellite imagery** allowing to derive
    - green spaces and lane boundaries

➢ **Many different data sources** for continuous updates and conflation into different layers of the HD map

Idea of the data model / meta layer „Road2Automation“ (R2A) 1(2)

The aim is to

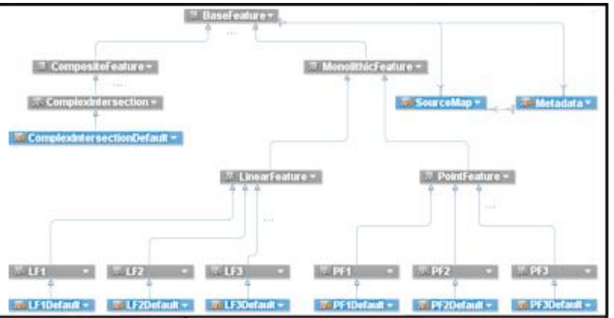
- supplement road information in today’s digital road maps with **georeferenced features** which are **relevant to**
  - **driving automation** and
  - **driving simulation**
- address maps of diverse levels of detail, precision and format (ranging from **HD and SD maps** from different vendors to **crowd-sourced data** from **OpenStreetMap (OSM)**)
- facilitate **transfer of the features between maps, based on different data sources** by a **meta layer** on top of all source and target maps, together with appropriate **runtime modules for location referencing.** This supports
  - **map conflation** and **continuous map updates**
  - use cases, where information from **more than one type of map / more than one data source** is required.

Idea of the data model / meta layer „Road2Automation“ (R2A) 2(2)

References

via
- flexible reference ID
- OpenLR-reference
- Road network matching

R2A:
Data model
and meta-layer



R2A is a „hybrid“ of
- a data model
- a meta layer on top of „source maps“

…

OpenDRIVE®
managing the road ahead

Road2Simulation

here

Different map formats (HD and SD formats)

Examples for use cases addressed by R2A 1(4)

A: Driving automation

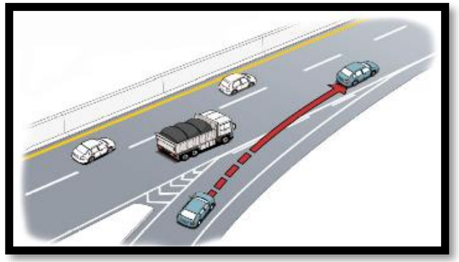
- Global path planning & (large and even small scale) localization
    - Relevant features (already available in SD maps):
        - name, type and width of the streets,
        - public speed limits
        - (OSM) track data
        - topology of the road network
- Safety of autonomous transport
    - Relevant features:
        - Information about complex intersections with attributes indicating e.g.
            - poor visibility of arms
            - absence of traffic lights
            - presence of many fast or wide lanes,
            - presence of short green light periods,
            - accident hotspots
        - Dangerous turns or bends

Examples for use cases addressed by R2A 2(4)




- Safety of autonomous transport (continued)
  - Relevant features:
    - horizontal and vertical curves with their radius and pitch
    - Information with relevance to the sensor system:
      - quality of lane markings
      - presence of tunnels or guardrail anti-glare panels
      - presence of steaming manholes

- “Transition areas” = lane sections, where either smart infrastructure has to exist or the driver must take over driving upon entering
  - Examples:
    - work zones
    - merging areas, lane drops
    - no automation zones


Examples for use cases addressed by R2A 3(4)

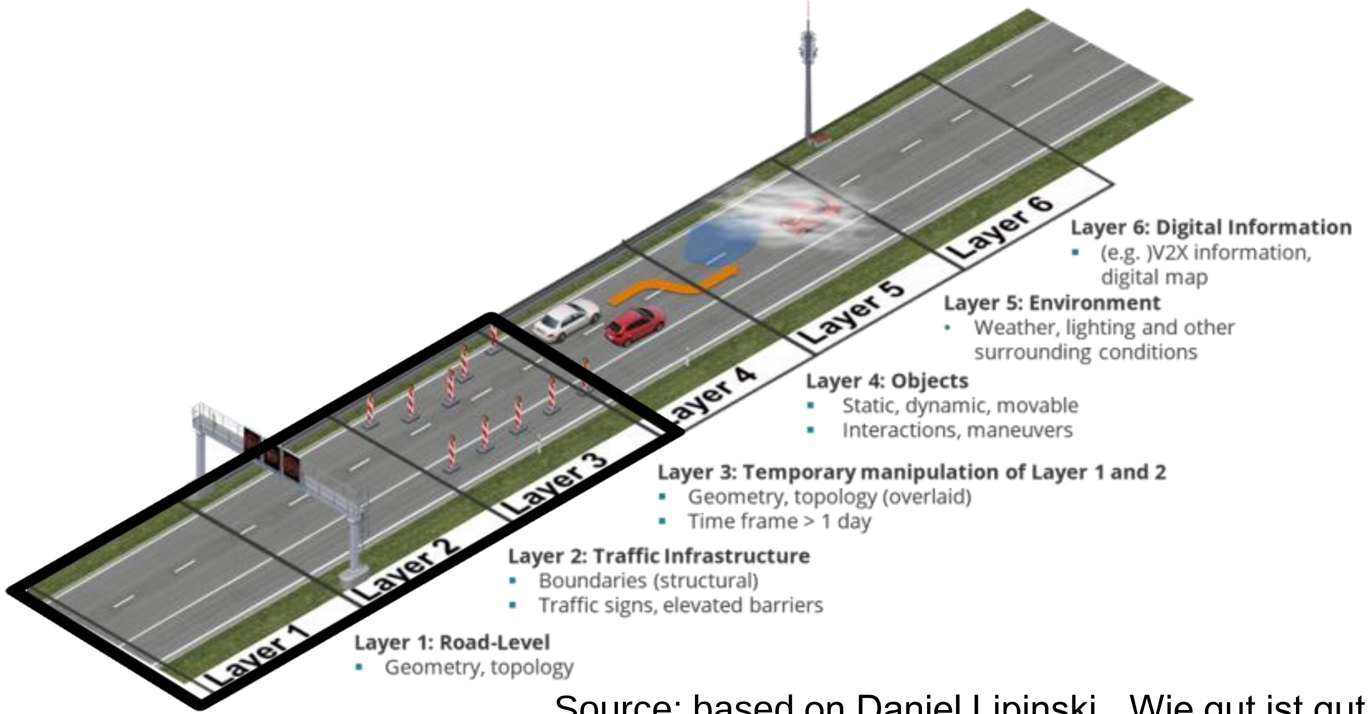
- Energy efficient driving (by acceleration optimization)
    - Relevant features:
        - intersections
        - slopes
        - presence of tunnels
- Curve or hill warnings
    - Relevant features:
        - curves (radius / pitch)
        - slopes
- Predictive cornering light
    - Relevant features:
        - curve radius

Source: Volkswagen Communications, Arteon assistance systems, “Active Lighting System”

Examples for use cases addressed by R2A 4(4)

B: Driving simulation, especially for testing partial vehicle automations / ADAS

- Same situation as for driving automation: use of **many different data sources**
- R2A provides a **meta layer** for the linkage between possible different sources for the **static content of a scenario**



Source: based on Daniel Lipinski, „Wie gut ist gut genug?“, Closing event of project PEGASUS

The two purposes of R2A

R2A meta layer

In order to establish a reference to the **location of an R2A feature in a source map**, R2A links back to:

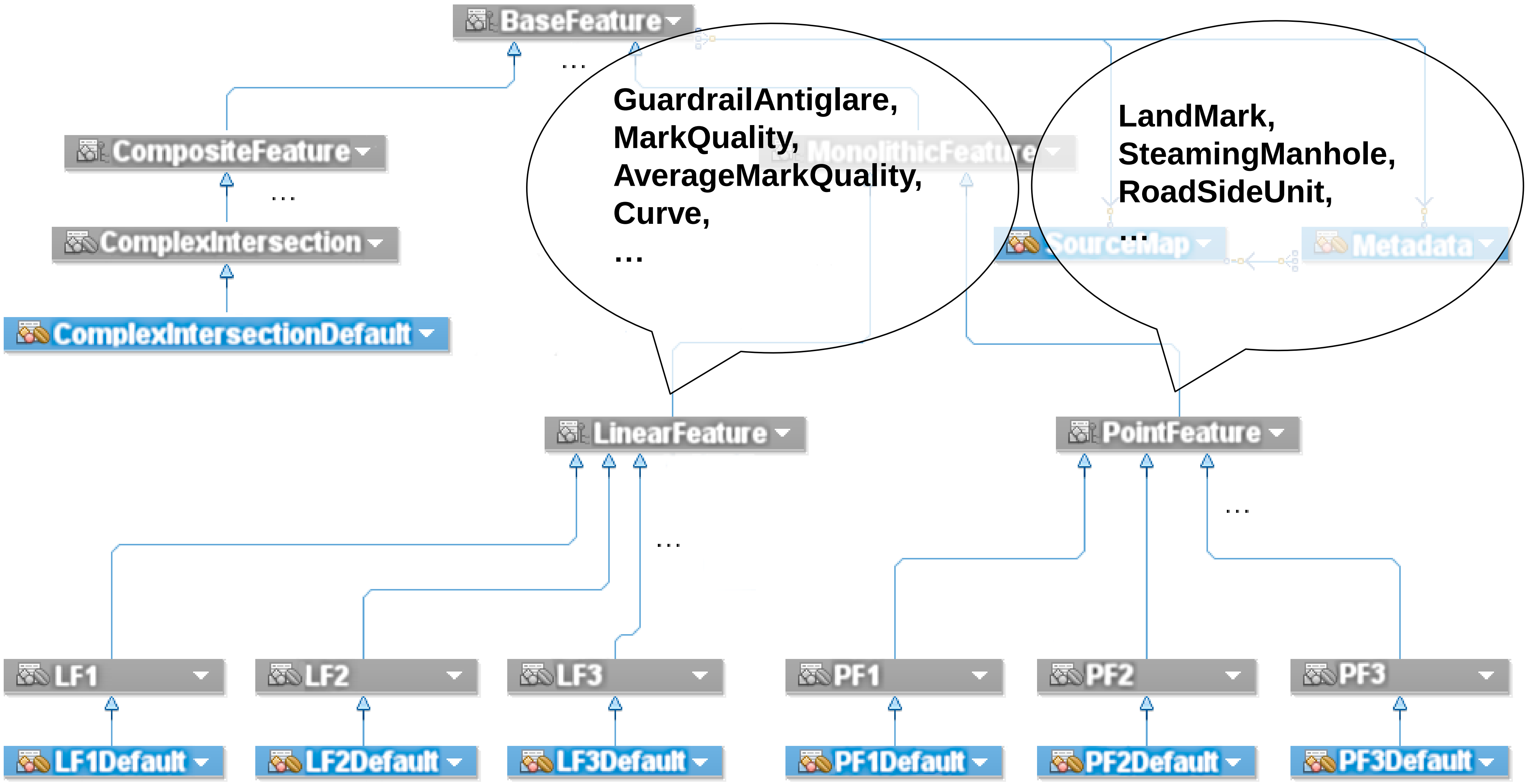
- Features in HD maps, often obtained by terrestial mobile mapping (in OpenDRIVE or Road2Simulation format)
  - Road reference lines (Road2Simulation)
  - Roads and lanes (OpenDRIVE)
  - Junctions or junction groups (OpenDRIVE)
- Features in SD maps from OpenStreetMap, HERE, or TomTom
  - Road segments (e.g. HERE (GDF) edges, or OSM ways)

R2A data model

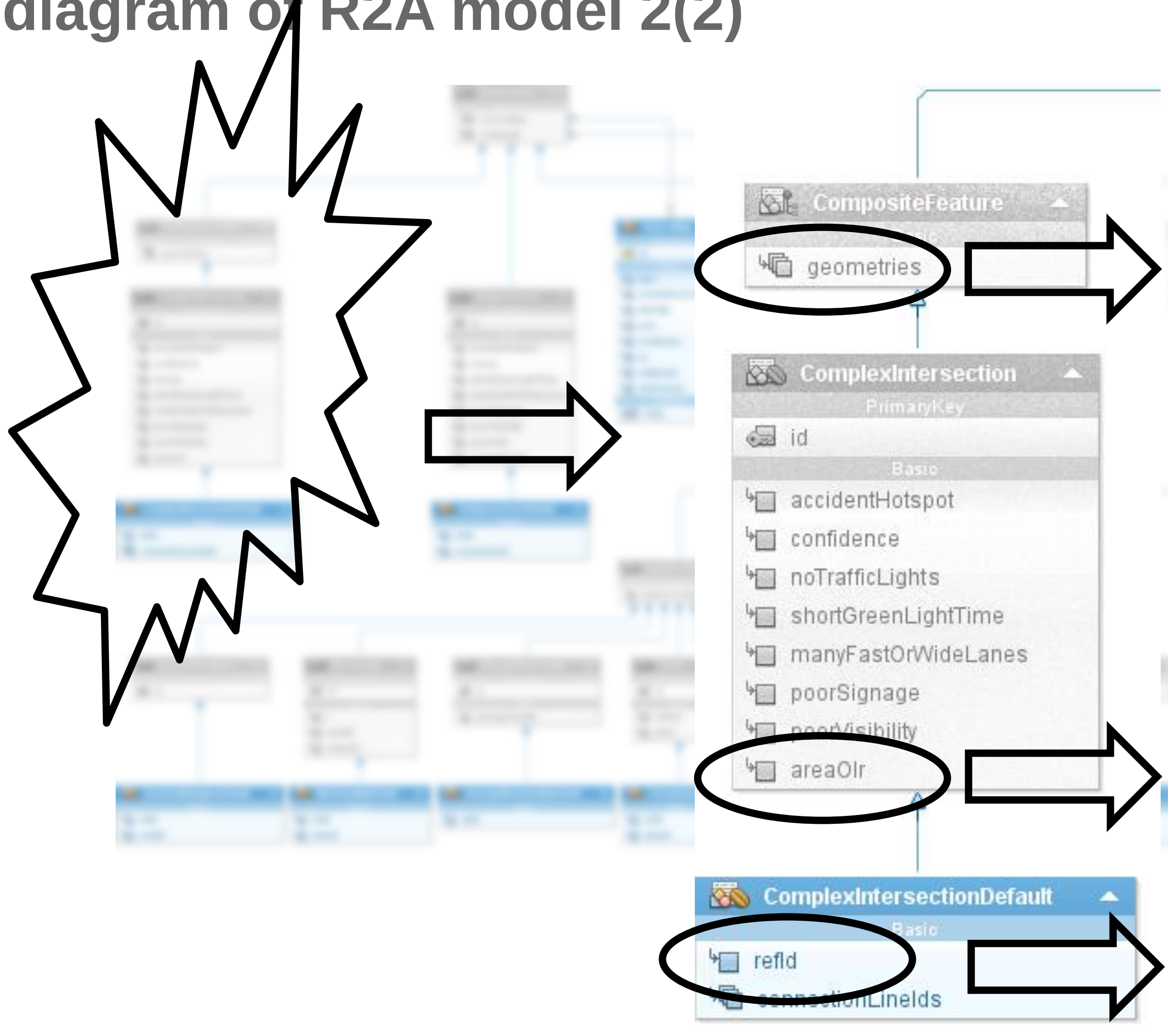
Feature attributes in the model are populated by:

- Attributes originally contained in the (HD or SD) maps
  - Road topology, road geometry, tunnels, lane markings, …
- Attributes filled with data from data collections (e.g. by mobile mapping, remote sensing techniques such as image flight) or with data derived by post-processing
  - Accident hotspots, poor visibility of junction arms, curve radius or pitch
  - Quality of lane markings
  - Locations of road side units, blue tooth sensors, landmarks, …

Class diagram of R2A model 1(2)



Class diagram of R2A model 2(2)



3D geometry, for example

- **Point Z (605044.419819 5791949.77898 128.12)**

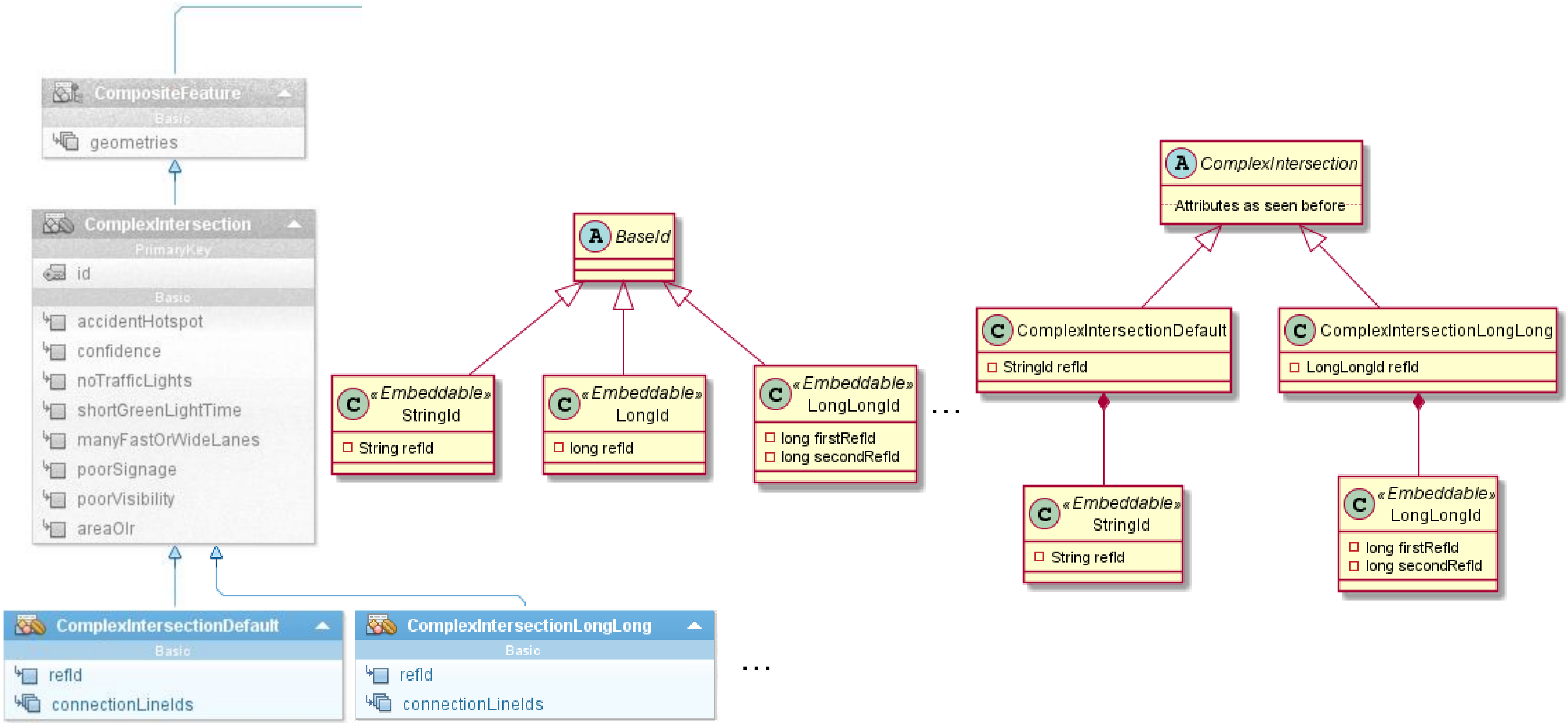
or

- **LineString Z (605059.7409 5791956.6 128.12, 605014.3896 5791935.49 128.22)**

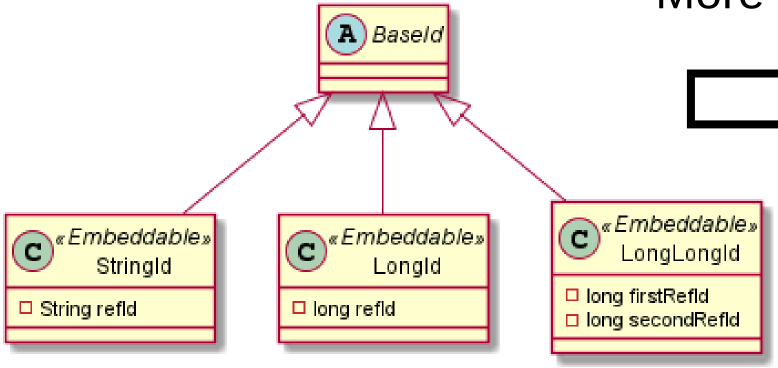
Base64 encoded OpenLR string, for example
CwOiYCUMoBNWAv9P/+MSBg==

Reference identifier of a default type (StringId)
Intended default use: reference to an OpenDRIVE <junctionGroup>

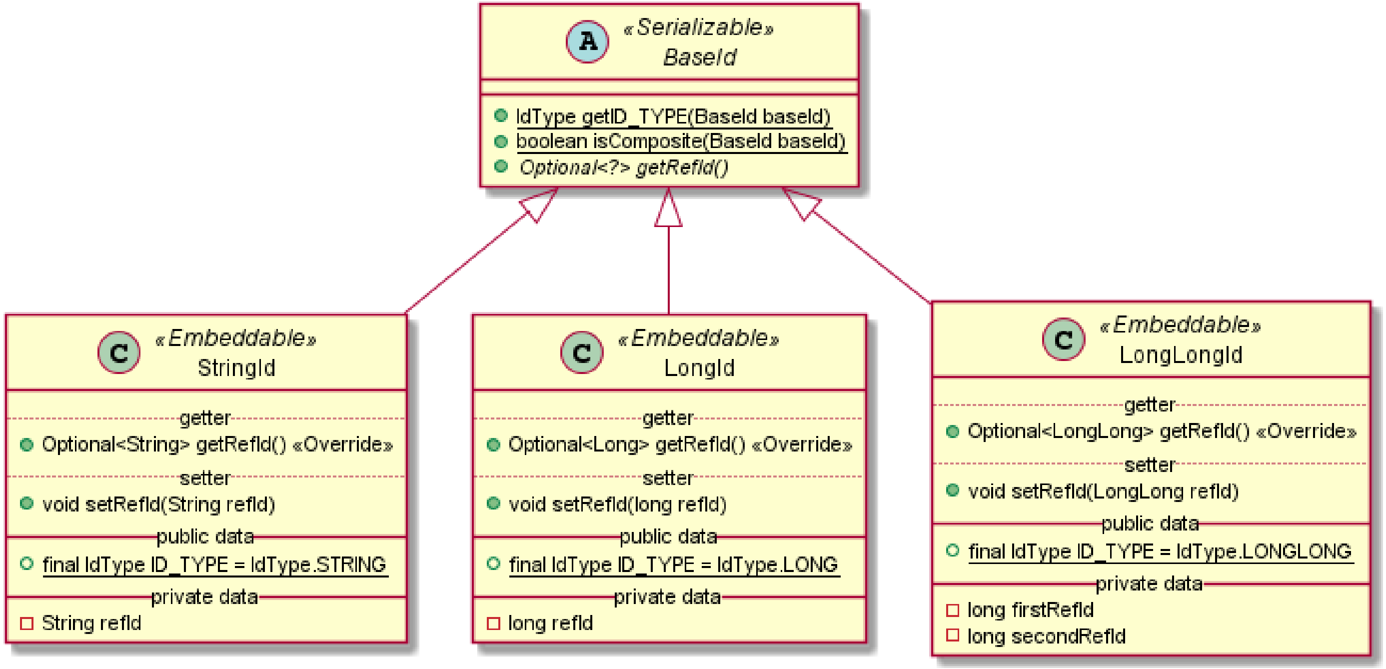
Flexible reference identifiers 1(2)



Flexible reference identifiers 2(2)

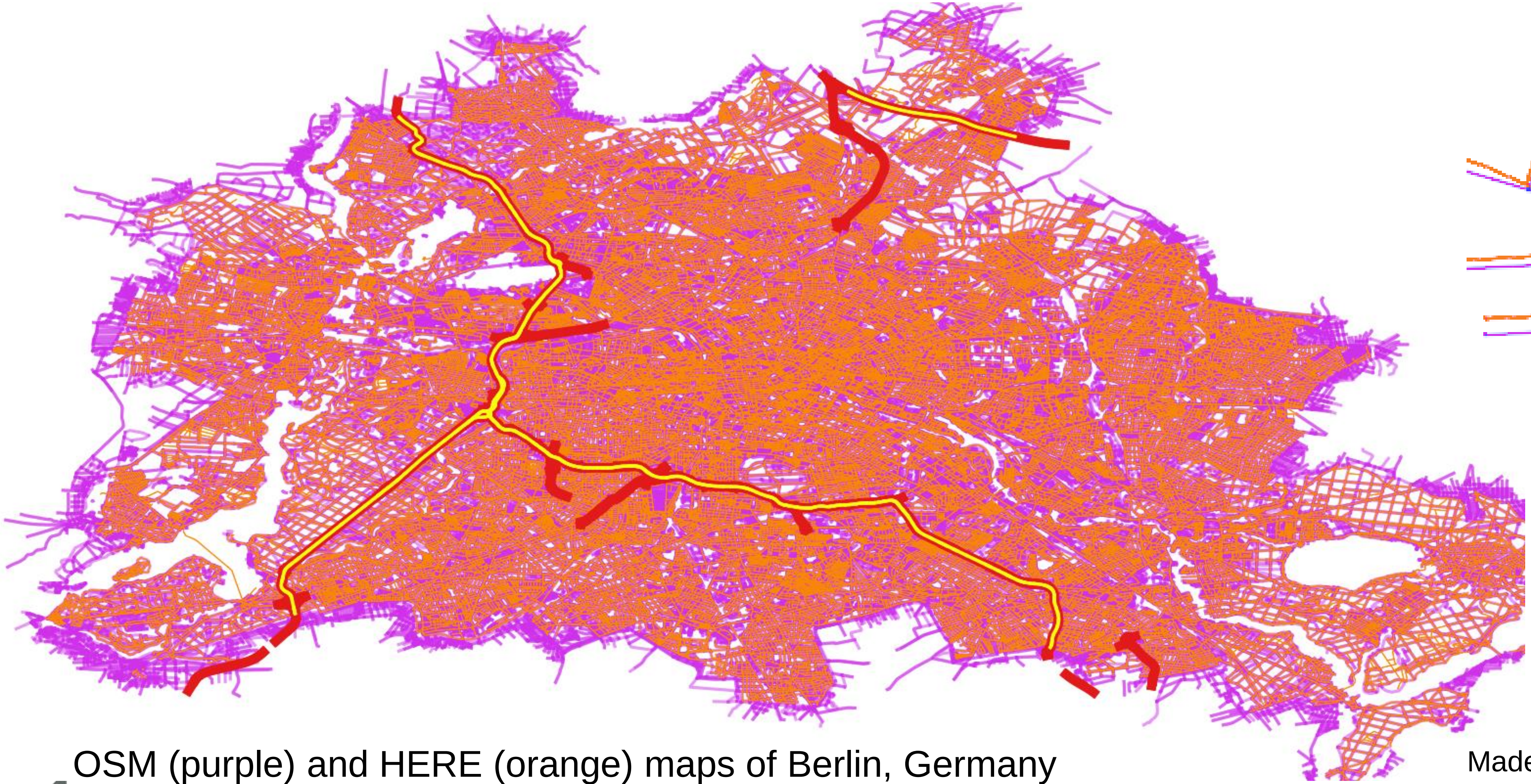


More detailed:



- Design principles:
  - Abstract classes which **force** derived concrete classes **to implement a common interface** (for instance the getter and setter for an attribute `refId`)
  - This allows for **generic type-agnostic code** as well as for **dynamic method dispatch** based on the actual key type as given by the static attribute `ID_TYPE`
  - This supports the use of **runtime polymorphism** and of object oriented (Java) design patterns

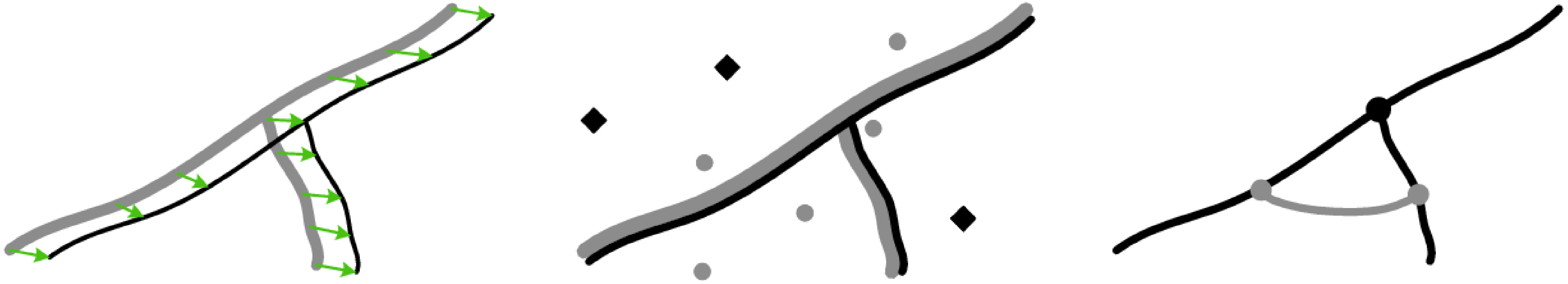
Transfer of features between dissimilar maps: R2A run time modules for inter-map matching (work in progress)



OSM (purple) and HERE (orange) maps of Berlin, Germany

Made with QGIS (https://qgis.org)

Road network matching and two applications (terminology of M. Zhang, PhD thesis 2009)



a) Road network matching

b) Road network integration

c) Road network conflation (often also called map conflation)

Source: Zhang, M.: Methods and Implementations of Road-Network Matching, Ph.D. thesis

Dynamic location referencing by OpenLR: line locations (routes)

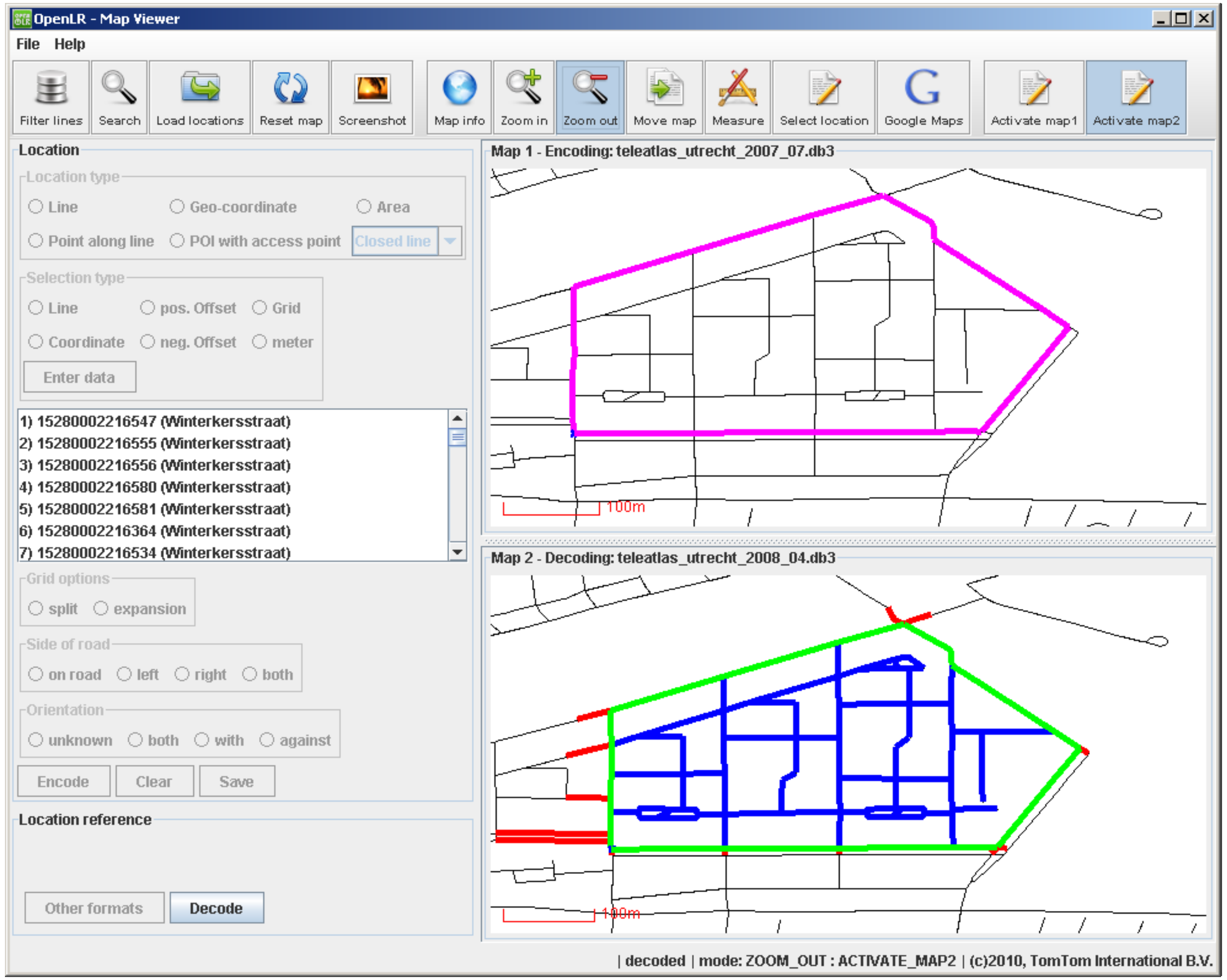
- OpenLR is a **bandwidth-efficient** protocol for the transfer of
    - linear locations
    - area locations

  from a sender to a receiver

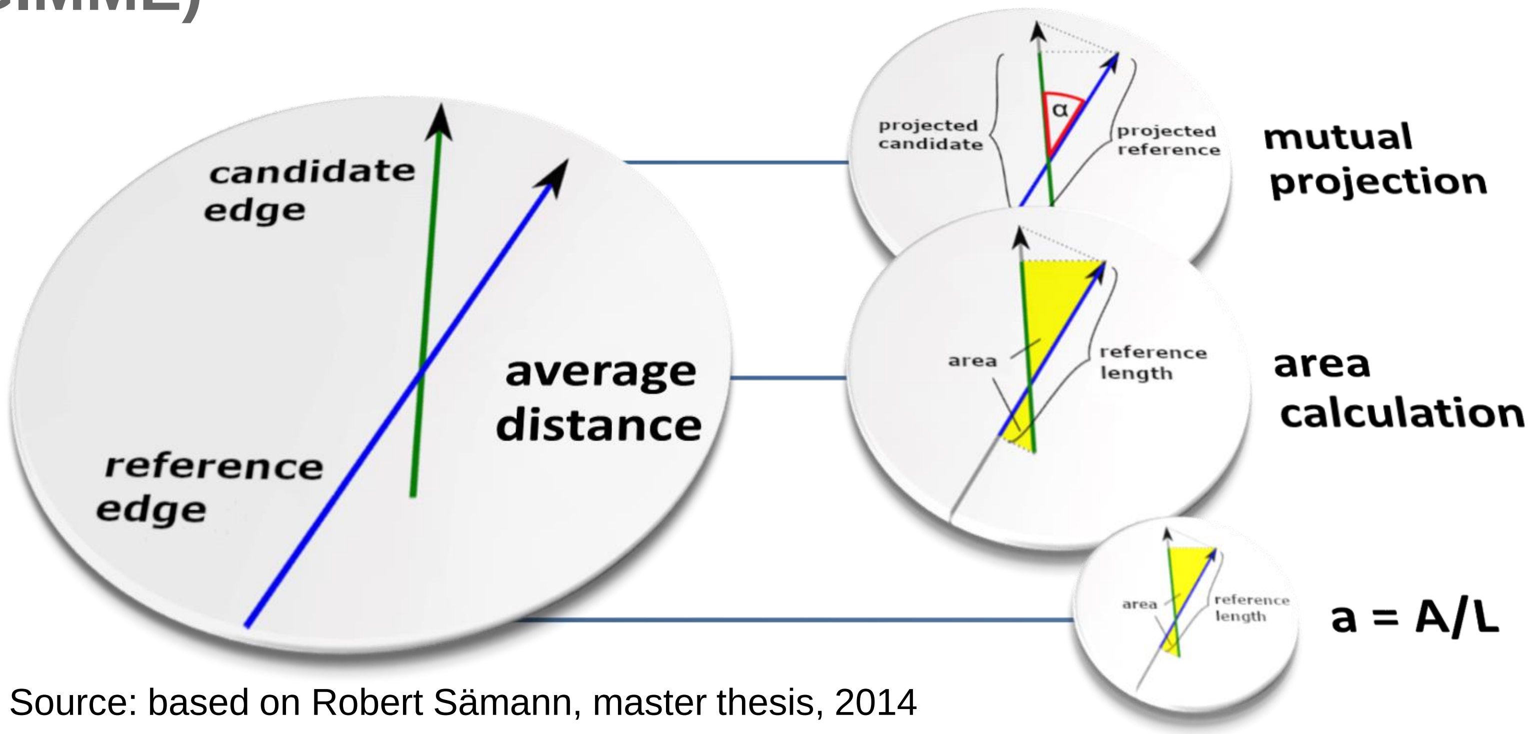
- They are encoded with the map of the sender and decoded with the map of the receiver

- Idea:
    - Instead of **transmitting every waypoint of the source route**, cover it by a concatenation of **shortest paths** between intermediate location reference points (LRP)
    - **Transmit only these LRP**

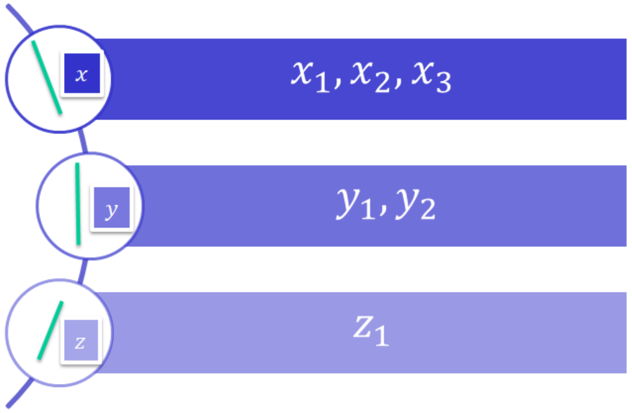
Dynamic location referencing by OpenLR: OpenLR: area locations



Road network matching with the Geometry Inter-Map Matching Extension (GIMME)



Source: based on Robert Sämann, master thesis, 2014



1. Geometry Matching (GM) orders candidate edges with respect to their “fitness” as a target edge matching a source edge
2. GIMME (R. Ebendt, L.C. Touko Tcheumadjeu, *Eur. Transp. Res. Rev.* 9, 38, 2017) optimizes the target route, starting on a collection of ordered candidate lists for every source edge

Comparison of OpenLR and road network matchers like GIMME

OpenLR

- **Success rates of more than 90%** when matching maps from different vendors, and 98-99%, when matching different map releases of the same vendor
- **Bandwidth-efficient** (by transmitting only as much LRP as needed)
- Reference implementation of OpenLR is available as **open source**
- **Map-agnostic**: sender does not need to know which map is used at the receiver side

Road network matchers

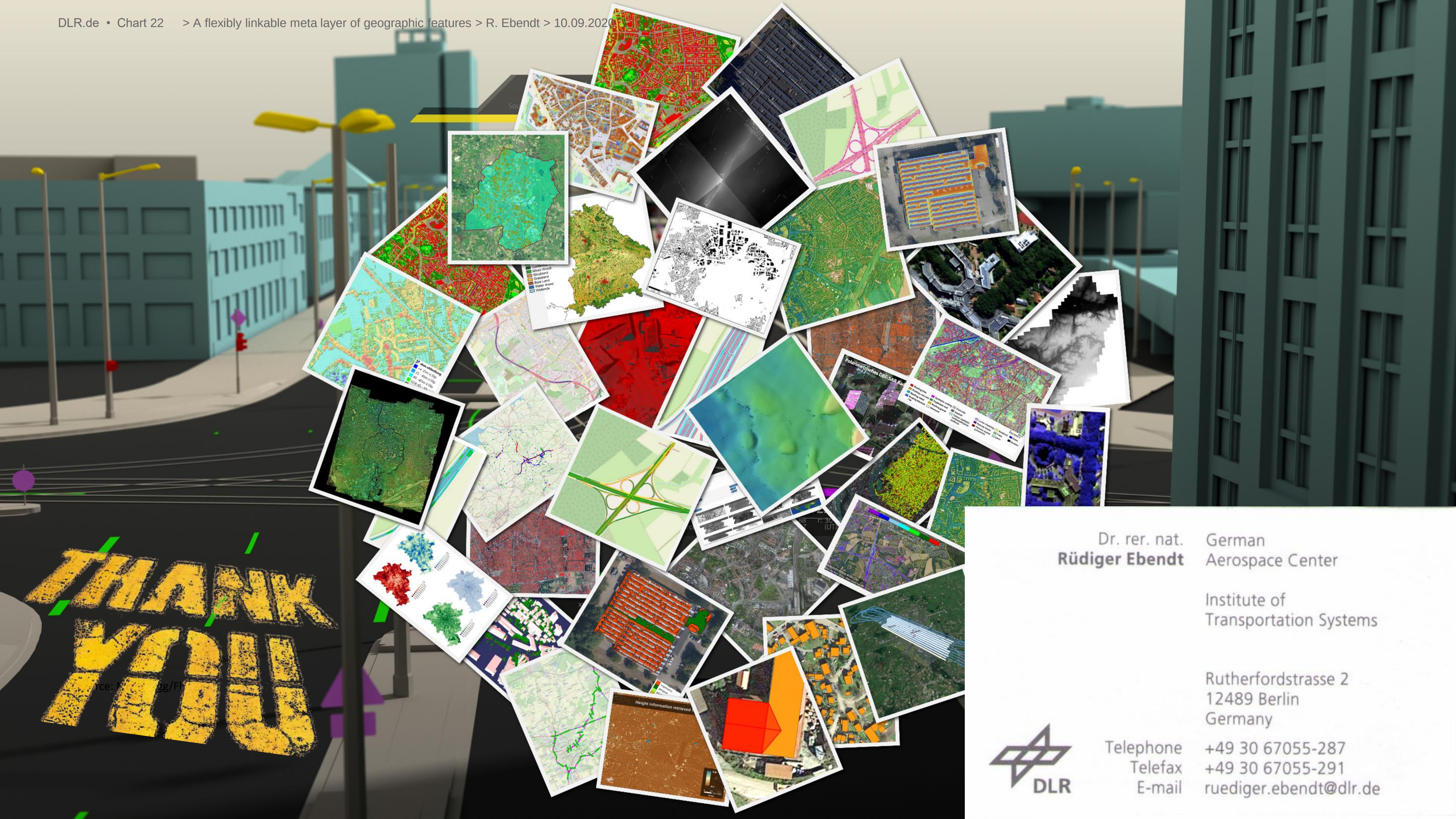
- **Very high success rates (GIMME: 99.7%)** when matching maps from different vendors, and almost perfect results (very close to 100%) when matching different map releases of the same vendor
- **Bandwidth-consuming**[1)] since complete geometries (line strings) must be transferred from sender to receiver
- **No actively maintained open source** implementations seem to be available
- **Map-independent** (works with any map pair from different vendors like HERE, TomTom, OpenStreetMap, …), but **receiver needs to have access to the same map as the sender**

1) bandwidth-efficient, when combined with a bandwidth-efficient method, but at the cost of additional runtime overhead

Conclusion

- A data model and meta layer called „Road2Automation“ (R2A) has been presented
- It addresses several use cases in driving automation and driving simulation
- Its main characteristics are
  - **flexibly extensible design**: the meta layer can establish links between maps or data sets in virtually any format
  - **support of feature transfer between maps** (as required for **map conflation, map integration, map updates**, as well as for some of the addressed use cases)

- Run time modules for inter-map matching are required alongside the model
- Adaption of already existing such modules (OpenLR, GIMME) to R2A is work in progress
- This work is currently done in two institutionally funded projects of German Aerospace Center
  - **KoFiF** („Kooperative Fahrzeugintelligenz und mechatronisches Fahrwerk“), subproject of the large scale project **Next Generation Car (NGC)**
  - Cross-sectoral project “**Digital Atlas**”



Dr. rer. nat.
Rüdiger Ebendt

German
Aerospace Center

Institute of
Transportation Systems

Rutherfordstrasse 2
12489 Berlin
Germany

Telephone +49 30 67055-287
Telefax +49 30 67055-291
E-mail ruediger.ebendt@dlr.de

DLR